On the Addition-Products of the Aromatic Isocyanides.

INAUGURAL DISSERTATION

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BY

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ON THE ADDITION-PRODUCTS OF THE AROMATIC ISOCYANIDES.

The compounds known as isocyanides were discovered almost simultaneously by Hofman[1] and by Gautier.[2] The latter supposed them to be bases, $\left.\begin{matrix}R\\C^{II}\end{matrix}\right\}N^{III}$, reacting with haloid acids like ammonia, giving $\left.\begin{matrix}R\\C^{II}\end{matrix}\right\}N^{V}.HX$. For this reason he called them carbylamines. That the isocyanides have no basic properties was shown by Nef,[3] who studied exhaustively the phenyl and *o*-tolyl isocyanides. Nef was the first to grasp the fact that the most characteristic property of the isonitriles is their power of adding to the carbon atom of the isocyanogen radicle, two monovalent atoms or groups, thus proving the presence of bivalent carbon.

The work which follows was carried out under the direction of Dr. Nef and consists chiefly of a general study of the addition-products of *p*-tolyl isocyanide and a study of some of the reactions of one of the addition-products of phenyl isocyanide.

As is to be expected, the reactivity of *p*-tolyl isocyanide is about the same as that of the other aromatic isonitriles and its addition-products are similar. Besides the addition of chlorine, which was accomplished by Nef,[4] the author has effected the following additions:

1. Of sulphur; forming *p*-tolyl mustard-oil:

$$C_7H_7N:C + S = C_7H_7N:C:S.$$

2. Of sulphuretted hydrogen, and mercaptans; giving thioform-*p*-toluide and its alkyl ethers:

$$C_7H_7N:C + H_2S = C_7H_7N:C{<}^{H}_{SH},$$

$$C_7H_7N:C + RSH = C_7H_7N:C{<}^{H}_{SR}.$$

[1] Ann. Chem. (Liebig) **144**, 114; **146**, 107.
[2] Ann. Chim. phys. [4] **17**, 103.
[3] Ann. Chem. (Liebig) **270**, 267.
[4] *Ibid.* **270**, 321.

3. Of alcohols; giving imidoformic ethers:

$$C_7H_7N:C + ROH = C_7H_7N:C<^{H}_{OR}.$$

4. Of hydrogen; giving methyl-*p*-toluidine:

$$C_7H_7N:C + 4H = C_7H_7NHCH_3.$$

5. Of amines, giving amidines:

$$C_7H_7N:C + RNH_2 = C_7H_7N:C<^{H}_{NHR}.$$

6. Of organic-acid chlorides, giving imide chlorides:

$$C_7H_7N:C + R.COCl = C_7H_7N:C<^{Cl}_{CO.R}.$$

Preparation of Paratolyl Isocyanide.[1]

This substance was made according to Hofmann's method for the preparation of the isonitriles. The yield is always poor, the best being obtained as follows: A solution of 210 grams caustic potash in 800 cc. alcohol (95 per cent.) is warmed to about 50° and a solution of 100 grams *p*-toluidine in 190 grams chloroform is slowly added by means of a dropping-funnel. Reaction at once sets in, accompanied by the separation of potassium chloride and the evolution of heat. It is necessary to cool continually, the temperature being best kept at a little over 50°. The reaction is much less violent toward the end and is never complete. After standing a short time, the alcohol and unchanged chloroform are distilled off on the water-bath, and the residue, after the addition of a quantity of water sufficient to dissolve the potassium chloride, is distilled with steam. A mixture of *p*-toluidine and *p*-tolyl isocyanide goes over as an oil of slight yellow color. This is taken up with ether and washed with 120 grams hydrochloric acid (sp. gr. 1.20), previously divided into two portions and largely diluted. It is best to do this washing as rapidly as possible, for the isocyanides react very easily with the amine hydrochlorides.[2] To this end it is well to dilute the hydrochloric acid as much as the size of the separatory funnel used will allow, and to warm it to about 30°; for otherwise the di-*p*-tolylformamidine, which is always formed, gives troublesome emulsions, as it is only slightly soluble in cold water. As soon as the amidine hydrochloride is all removed by washing with water the ethereal solution is washed once with dilute alkali

[1] Nef: Ann. Chem. (Liebig) **270**, 320.

[2] See p. 10.

and dried over caustic potash. After distilling off the ether, the isonitrile is distilled at reduced pressure.

Paratolyl isocyanide boils at 99°[1] at 32 mm. pressure ("99° at 36 mm." [Nef]), and has a specific gravity of 0.96 at 24° (Westphal). On cooling it solidifies to a crystalline solid which melts at 21°. Its odor does not differ much from that of the other aromatic isonitriles, being less disagreeable than that of phenyl isocyanide. Its taste is extremely bitter, as may be noticed by inhaling a small quantity of its vapor at ordinary temperatures. No unpleasant physiological effects were experienced by the author in working with this substance. When first distilled it is colorless, but immediately begins to take on a green color and finally becomes brown. It is best kept in the dark at a temperature below its melting-point. Under these conditions it may be kept for several weeks with only slight change. On heating polymerization takes place, interfering with such reactions of this compound as require a high temperature for their accomplishment.

Action of Sulphur.—5 grams *p*-tolyl isocyanide and the calculated amount of sulphur dissolved in carbon disulphide were heated in a sealed tube for six hours at 120°–140°. On opening the tube no smell of isocyanide was left. After the carbon disulphide had been distilled off, the mustard-oil was separated from the polymerized isonitrile by distilling with steam. The distillate was extracted with ether and the solution dried with chloride of calcium. After distilling off the ether the mustard-oil boiled at 242°–243° and melted at 26°. Hofmann[2] gives the boiling-point 237° and the melting-point 26°. Sulphur was determined by the method of Carius.

0.1538 gram substance gave 0.2409 gram $BaSO_4$.

	Calculated for C_8H_7NS.	Found.
S	21.47	21.55

Paratolyl isocyanide seems to have a great tendency to take up sulphur from the compounds of sulphur with the halogens and form mustard-oils. A solution of bromine in carbon bisulphide when treated with isocyanide gave considerable quantities of

[1] The temperatures given in this paper were measured by a thermometer which was carefully compared with a standard set of Gerhardt's short thermometers. At no point between 0 and 200° was there a variation of one degree.

[2] Ber. d. chem. Ges. **1**, 173.

mustard-oil. The odor of mustard-oil was noticed on vulcanized rubber which had been exposed for some time to the vapor of isonitrile. Mustard-oil was the only compound that could be isolated from the substances obtained by the reaction of thiophosgene on isocyanide.

Sulphur monochloride and *p*-tolyl isocyanide react with great violence. Several experiments were carried out, using carbon disulphide as a diluent. Five grams isocyanide and 3 grams sulphur monochloride were used in each experiment. The only products that could be identified were polymerized isonitrile and mustard-oil, the latter being obtained in quantities varying from 2.5 to 4 grams in the several experiments.

5 grams *p*-tolyl isocyanide and 2.2 grams sulphur dichloride were mixed in carbon-disulphide solution, moisture was carefully excluded, and the mixture was cooled by means of salt and ice. On boiling off the carbon disulphide and distilling with steam, 3.5 grams of an oil were obtained which, after taking up with ether and drying, boiled from 225°–240°. This was proved to be a mixture of *p*-tolyl mustard-oil and *p*-tolylimido carbonyl chloride by treating with an excess of *p*-toluidine, which gave 4.5 grams sulphocarbtoluide and 1.1 grams *α*-tri-*p*-tolylguanidine. This reaction may be explained in two ways: The sulphur dichloride may first act simply as a chlorinating agent, giving the imidocarbonyl chloride and sulphur monochloride, which reacts with more isonitrile, giving mustard-oil; or the sulphur dichloride may add to the isonitrile, giving $p\text{-}CH_3.C_6H_4.N=C<^{Cl}_{S.Cl}$. That this body should be unstable—easily giving mustard-oil and imidophosgene—is likely, from the fact that no similar body has been observed in the preparation of phenylimidocarbonyl chloride by the chlorination of phenyl mustard-oil,[1] which should give $C_6H_5.N=C<^{Cl}_{S.Cl}$ as an intermediate product.

Action of Hydrogen Sulphide.—That phenyl isocyanide adds sulphuretted hydrogen was shown by Hofmann.[2] Nef[3] has obtained thioform-*o*-toluide by the action of an alcoholic solution of hydrogen sulphide on *o*-tolyl isocyanide. Paratolyl isocyanide gives the corresponding para derivative. 50 cc. of 98-per cent. alcohol were saturated with sulphuretted hydrogen at 0°; 2 grams

[1] Sell and Zierold: Ber. d. chem. Ges. **7**, 1228; Nef: Ann. Chem. (Liebig) **270**, 284.
[2] Ber. d. chem. Ges. **10**, 1095. [3] Ann. Chem. (Liebig) **270**, 313.

of *p*-tolyl isocyanide were added, and the mixture was heated in a sealed tube for eight hours at 100°. On cooling, brown needles separated out, and more were obtained from the mother-liquor by evaporation, giving in all 1.1 grams crude product. This was recrystallized from ligroïn (boiling-point 70°–80°), using animal charcoal; and twice from benzene, giving nearly colorless, flat needles that melted at 175°–176°. Dried *in vacuo* over sulphuric acid and analyzed by the method of Carius:

0.1573 gram substance gave 0.2405 gram $BaSO_4$.

	Calculated for C_8H_9NS.	Found.
S	21.19	21.04

Senier[1] obtained thioform-*p*-toluide from form-*p*-toluide and phosphorus pentasulphide. He describes it as a yellow substance melting at 173.5°.

Paratolylimido thioformic ethyl ester,

$$CH_3.C_6H_4.N=C<^{H}_{S.C_2H_5}.$$

5 grams *p*-tolyl isocyanide and 2.5 grams ethyl mercaptan were heated in a sealed tube for two and one-half hours at 100°. The reaction was not complete at this point, for on opening the tube the odor of each of the substances could be distinguished. The product was heated on a water-bath to drive off the unchanged mercaptan and then distilled. On the second distillation 3 grams of a slightly yellow oil were obtained, which boiled at 250°–252°. On analysis:

0.2080 gram substance gave 0.1355 gram H_2O and 0.5101 gram CO_2.

0.2712 gram substance gave 18.6 cc. N at 17.5° and 744.7 mm.

0.1659 gram substance gave 0.2133 gram $BaSO_4$ (Carius).

	Calculated for $C_{10}H_{13}NS$.	Found.
C	67.04	66.88
H	7.26	7.24
N	7.82	7.81
S	17.87	17.69

The odor of this ester is disagreeable, reminding one of the imido ethers and also of sulphur derivatives. By treatment with aqueous hydrochloric acid it is converted into di-*p*-tolylformamidine hydrochloride.[2] Wallach and Wusten[3] have obtained

[1] Ber. d. chem. Ges. **18**, 2295.

[2] This substance was obtained so often in this work that an analysis of it each time was deemed unnecessary. See page 10: action of amines.

[3] Ber. d. chem. Ges. **16**, 144.

p-tolylimido-thioacetic ethyl ester (boiling-point, 271°–273°) and phenylimido-thioformic methyl ester (boiling-point, 230°–240°). These with hydrochloric acid give corresponding amidines.

Paratolylimidoformic ethyl ester, $CH_3.C_6H_4.N=C<^{H}_{O.C_2H_5}$.—5 grams *p*-tolyl isocyanide and a solution made by dissolving 1 gram sodium in 20 cc. absolute alcohol were heated in a sealed tube for six hours at 120°. No smell of isonitrile was left. On pouring the contents of the tube into quite a quantity of water, a brown ethereal oil separated out. This was taken up with ether, and the solution, after washing to get rid of alcohol, was dried over calcium chloride. The ether was distilled off and the residue fractioned. Most of it came over between 227° and 234°. This fraction (4.1 grams) was redistilled, boiling at 231°–232° at 743 mm. On analysis:

0.2072 gram substance gave 0.1488 gram H_2O and 0.5572 gram CO_2.

0.2375 gram substance gave 19.1 cc. N at 23° and 736.1 mm.

	Calculated for $C_{10}H_{13}NO$.	Found.
C	73.62	73.33
H	7.97	7.98
N	8.59	8.82

This imido-ether is a pleasant-smelling oil of a slightly yellow color. On cooling to about 0° it solidifies to a crystalline solid which melts at 8°. By treatment with aqueous hydrochloric acid (dilute or concentrated), it could be converted into di-*p*-tolylformamidine hydrochloride, which gave the free base melting at 140°.

Action of Methyl Alcohol.—5 grams *p*-tolyl isocyanide and a solution made by dissolving 1 gram sodium in 10 cc. methyl alcohol were heated in a sealed tube for three hours at 130°. On cooling, quite a quantity of crystals, 2 grams, separated out. After recrystallization from alcohol, they melted at 140° and were identified with di-*p*-tolylformamidine obtained by other methods. The filtrate was poured into an excess of water. The oil which separated out was taken up with ether, and the ethereal solution, after washing several times with water, was dried over calcium chloride. The ether was then evaporated and the residue distilled, giving about a cubic centimeter of a slightly yellow oil which boiled between 215° and 220°. This was undoubtedly *p*-tolylimido-

formic methyl ester (boiling-point, 216°–218°),[1] for it resembled the ethyl ester in odor and appearance, and on treatment with dilute hydrochloric acid gave di-*p*-tolylformamidine.

The above experiments make plain the reason for the failure of former attempts to obtain the alcohol addition-products of the isonitriles. The treatment has been too energetic, and the unstable imido-ethers have gone over at the temperature of the reaction to formamidines.

Reduction of Paratolyl Isocyanide.—Nascent hydrogen converts *p*-tolyl isocyanide into monomethyl-*p*-toluidine. 8 grams isonitrile were dissolved in 70 cc. amyl alcohol; the solution was heated to boiling in a flask with reversed condenser attached, and 7.5 grams sodium gradually added. As soon as the sodium had all disappeared, the solution was cooled and washed with water. The smell of isocyanide had all disappeared. The solution was then partially dried with lime and distilled. After the amyl alcohol had distilled out, 4 grams of slightly colored oil came over between 180° and 215°, 3.5 grams between 215° and 225°, and 3 grams between 225° and 250°. These fractions were then treated with dilute hydrochloric acid. The first two gave no precipitate, but the third gave 0.4 gram of di-*p*-tolylformamidine hydrochloride, probably due to the decomposition of *p*-tolylimidoformic amyl ester, which could very easily be formed during the reaction. The acid solution was heated on the water-bath till all odor of amyl alcohol had disappeared. It was then treated with sodium nitrite, and the nitrosamine extracted with ether. After repeated crystallizations from alcohol and ether, it melted at 48°–49°. This nitrosamine was reduced with tin and hydrochloric acid. The base was then set free, distilled with steam, and the distillate extracted with ether. After drying with caustic potash, distilling off the ether, and distilling the residue, 2.5 grams of monomethyl-*p*-toluidine were obtained which boiled at 208°. On treatment with acetic anhydride, methylacet-*p*-toluide[2] was obtained, which, after several crystallizations from ligroïn, melted at 79°.

Action of Amines.—Weith[3] has shown that phenyl isocyanide unites with aniline to give diphenylformamidine. This observation has been confirmed by Nef,[4] who also obtained di-*o*-tolylformamidine[5] from *o*-tolyl isocyanide and *o*-toluidine.

[1] Comstock and Clapp: Am. Chem. Jl. **13**, 527.
[2] Thomson: Ber. d. chem. Ges. **10**, 1582.
[3] Ber. d. chem. Ges. **9**, 454.
[4] Ann. Chem. (Liebig) **270**, 281.
[5] *Ibid.* **270**, 312.

4 grams *p*-tolyl isocyanide were mixed with 5 grams *p*-toluidine and heated on a metal-bath to a temperature of about 200°. Much polymerization took place, but di-*p*-tolylformamidine could be separated from the resultant tarry mass by means of boiling ligroïn (boiling-point, 70°–80°), in which it is somewhat soluble. After several recrystallizations from ligroïn, and one from alcohol, 2 grams of colorless needles was obtained, which melted at 140°.[1]

In a nitrogen determination 0.0837 gram substance gave 9 cc. N at 16° and 749.4 mm.

Calculated for $C_{15}H_{16}N_2$.	Found.
12.5	12.4

A much smoother reaction is obtained by means of the amine hydrochlorides in alcoholic solution, or even in water solution in contact with an ethereal solution of the isocyanide. On mixing alcoholic solutions of the substances in the cold, no immediate reaction is noticeable; but after standing for a very few minutes, a bulky precipitate of white needles separates out, which, if the solution is not too dilute, entirely fills the liquid. This precipitate is the hydrochloride of di-*p*-tolylformamidine, and from it the free base can be easily obtained by means of alkalies. This reaction does not seem to take place quantitatively, for the yield is never equal to the theoretical, nor does the odor of isonitrile disappear from the solution even if the amine hydrochloride is present in slight excess.

On mixing aniline hydrochloride and *p*-tolyl isocyanide in alcoholic solution, a similar crystalline hydrochloride is obtained; but neither this salt nor the free base obtained from it could be obtained of constant melting-point and composition. The mixed dialkylated formamidine seems to tend to go over into a mixture of the two simple ones. This result is entirely analogous to that obtained by Nef[2] with the phenyl-*o*-tolylformamidine. Monoethylaniline hydrochloride reacts similarly, but the product of the reaction was not investigated. Diethylaniline hydrochloride does not react, neither does phenylhydrazine hydrochloride nor ammonium chloride.

The isonitriles seem to react with all substances that contain a halogen atom loosely bound. Nef[3] has proved that the aromatic

[1] Senier: Ber. d. chem. Ges. **18**, 2296; Comstock and Clapp: Am. Chem. Jl. **13**, 527.
[2] Ann. Chem. (Liebig) **270**, 312. [3] *Ibid.* **270**, 282, 313, 321.

isocyanides react with the free halogens. Gautier[1] has shown that the aliphatic derivatives react with the haloid acids, and Nef[2] has obtained the same result with phenyl isocyanide. Nef[3] has also shown that the aromatic isocyanides add organic-acid chlorides, giving imide chlorides.

I have studied the reactions of *p*-tolyl isocyanide with a large number of chlorides. With hydrochloric acid, either dry or aqueous, it reacts with great violence. The reaction seems to be the same as in the case of the other isonitriles and the reaction-product was not carefully studied. With the chlorides of the negative elements it reacts in all cases tried, but in most cases[4] it does not seem to be possible to isolate the addition-products, since they immediately decompose, giving the original chloride and isocyanide which in this nascent state entirely polymerizes. With the organic-acid chlorides, however, much more tangible results were obtained.

Mesoxalparatoluide hydrate, $\begin{matrix} CH_3.C_6H_4.N{=}C{<}^{OH} \\ CH_3.C_6H_4.N{=}C{<}_{OH} \end{matrix} C{<}^{OH}_{OH}$. —

Phosgene reacts very energetically with *p*-tolyl isocyanide. A smooth reaction was obtained as follows: 9.5 grams *p*-tolyl isocyanide were mixed with a little more than an equal volume of absolute ether and cooled in a mixture of salt and snow. 10 cc. of phosgene, previously cooled in a freezing-mixture, were added, and the mixture was allowed to warm slowly to the temperature of the room, moisture being excluded by a chloride-of-calcium tube. After standing for thirty-six hours, it was heated for a short time on the water-bath to drive off the excess of phosgene. The reaction-product was a thick oil, colored dark by polymerized isonitrile, but was without a trace of isonitrile odor. It was not attempted to purify this imide chloride directly, but instead it was poured into an excess of cold water. It became solid slowly, without any marked evolution of heat. After pulverizing and treating thoroughly with cold water, the solid was filtered off and dried. From this crude product, mesoxal-*p*-toluide hydrate was obtained in a pure state by boiling with water, or more rapidly, by digestion with dilute alkalies.

It is almost insoluble in cold water, and a litre of boiling water dissolves only about 0.25 gram, which crystallizes out on cooling

[1] Ann. chim. phys. [4] **17**, 222 and 239. [2] Ann. Chem. (Liebig) **270**, 303.
[3] *Ibid.* **270**, 286 and 315 *et seq.* [4] See reaction with chlorides of sulphur, page 5.

in the form of fine colorless needles. These, pulverized and dried *in vacuo* over sulphuric acid, gave the following figures on analysis:

0.1841 gram substance gave 0.0969 gram H_2O and 0.4346 gram CO_2.

0.1897 gram substance gave 0.4508 gram CO_2 (H_2O lost).

0.1830 gram substance gave 14.2 cc. N at 9° and 757 mm.

	Calculated for $C_{17}H_{18}N_2O_4$.	Found.	
C	64.97	64.39	64.80
H	5.73	5.85	...
N	8.92	9.31	...

If heated rapidly the hydrate becomes yellow at a little above 100°, and melts to a sticky resinous mass at 120°–130°. If heated more slowly, the water goes off gradually and the residue melts at 187°. Mesoxal-*p*-toluide hydrate has acid properties. It does not color litmus, but it dissolves in sodic hydrate and is precipitated unchanged by hydrochloric acid. It dissolves readily in most organic solvents, but on heating these solutions they become yellow, showing the conversion of the toluide hydrate into the toluide. Both the pure hydrate and the crude product mentioned above are readily soluble in alcohol, being converted thereby more or less completely into

Mesoxalparatoluide alcoholate, $\begin{matrix} CH_3.C_6H_4.N=C\lessgtr^{OH}_{C\lessgtr^{OH}_{OC_2H_5}} \\ CH_3.C_6H_4.N=C\lessgtr^{OH}_{C\lessgtr^{OH}_{OC_2H_5}} \end{matrix}$.

—This was obtained chiefly from the crude product by dissolving in alcohol and precipitating with water and then recrystallizing from dilute alcohol and dilute acetone. In order to be sure that the hydrate was all converted into the alcoholate, it was finally dissolved in absolute alcohol and boiled for an hour in a flask, to which a reversed condenser was attached. Then the alcohol was partly distilled off and, on cooling, the alcoholate crystallized out in colorless microscopic needles. Pulverized and dried over sulphuric acid *in vacuo*, they gave the following analytical figures:

0.1429 gram substance gave 0.0897 gram H_2O and 0.3491 gram CO_2.

0.2439 gram substance gave 16.6 cc. N at 9° and 752 mm.

	Calculated for $C_{19}H_{22}N_2O_4$.	Found.
C	66.66	66.61
H	6.43	6.97
N	8.19	8.12

In its physical properties the alcoholate resembles the hydrate very closely. By treatment with water a small quantity dissolves, being probably converted into the hydrate.

On heating, the alcoholate loses alcohol quantitatively, as the following experiment proves:

0.3965 gram alcoholate heated	3 hours at	95°	lost 0.0432 gram.
	3 hours at	105°–115°	" 0.0023 "
	8 hours at	95°–130°	" 0.0045 "
	3 hours at	110°–120°	" 0.0021 "
	3 hours at	110°–120°	" 0.0010 "
	3 hours at	110°–120°	" 0.0000 "
	23 hours at	90°–130°	" 0.0531 "

Calculated for loss of C_2H_6O.	Found.
13.45	13.49

The yellow powder left behind was

Mesoxalparatoluide, $CH_3.C_6H_4.N=C<\begin{matrix}OH\\C=O.\\OH\end{matrix}$—It was analyzed without further treatment:

0.1402 gram substance gave 0.0714 gram H_2O and 0.3542 gram CO_2.

	Calculated for $C_{17}H_{16}N_2O$.	Found.
C	68.92	68.87
H	5.41	5.66

Its melting-point was found to be 187°. It is soluble in the ordinary organic solvents, giving yellow solutions in such as contain no water or alcohol; but if these are present the solution is colorless and the substance is converted into the hydrate or alcoholate. It reacts with phenylhydrazine, but the reaction-product was not investigated.

Benzoylformoparatoluide, $CH_3.C_6H_4N.=C<\begin{matrix}OH\\CO.C_6H_5.\end{matrix}$—Benzoyl chloride and *p*-tolyl isocyanide react slowly on each other. 8 grams isonitrile and 9.6 grams benzoyl chloride were heated on a water-bath in a flask closed by a chloride-of-calcium tube, for ten hours. The smell of isonitrile had all disappeared, but polymerization had taken place to a considerable extent. In order to remove the polymerization-product, the tarry mixture was boiled out with several volumes of ligroïn (boiling-point, 70°–80°) and filtered hot. After distilling off the ligroïn, water was added to

decompose the chlorides, and the mixture was heated on the water-bath till all smell of benzoyl chloride had disappeared. The resultant solid was dissolved in ether and the solution washed with sodium carbonate to remove benzoic acid. After drying with calcium chloride the ether was partially distilled off, and the benzoylformic-*p*-toluide was allowed to crystallize out. After recrystallization from alcohol, ether, and finally from ligroïn, flat yellow needles were obtained which melted at 111°–113°. On analysis:

0.1350 gram substance gave 0.0718 gram H_2O and 0.3741 gram CO_2.

0.3738 gram substance gave 20.25 cc. N at 25° and 749 mm.

	Calculated for $C_{15}H_{13}NO_2$.	Found.
C	75.31	75.54
H	5.44	5.91
N	5.86	5.99

This substance is very slightly soluble in hot water, but is quite soluble in hot sodic-hydrate solution (1 : 30), from which it crystallizes unchanged on cooling and may also be precipitated by acids.

Pyruvic paratoluide, $CH_3.C_6H_4.N=C<\begin{matrix}OH\\COCH_3\end{matrix}$. — Acetyl chloride reacts with *p*-tolyl isocyanide much more readily than benzoyl chloride. If a mixture of these two substances be incautiously heated, the reaction is so violent that the whole mass chars. The addition was accomplished as follows: 9.5 grams of *p*-tolyl isocyanide and 7 grams acetyl chloride were mixed in a flask at the ordinary temperature. A reversed condenser closed by a chloride-of-calcium tube was attached and the flask was placed in a cold-water bath, which was then slowly heated to the boiling-point. After the water had boiled four minutes the flask was removed. As soon as the contents of the flask had cooled they were poured into 200 cc. of ice-water. After the mass had become solid it was pulverized and again treated with water, then filtered off and dried. 10 grams of crude product were obtained. This was recrystallized from 2.5 liters boiling water and finally from alcohol, giving 5 grams colorless scales which melted at 108°. On analysis:

0.1793 gram substance gave 0.1040 gram H_2O and 0.4460 gram CO_2.

0.2314 gram substance gave 16.7 cc. N at 13.5° and 754 mm.

	Calculated for $C_{10}H_{11}NO_2$.	Found.
C	67.79	67.83
H	6.21	6.44
N	7.91	8.47

It is easily soluble in boiling alcohol or ether, from which it crystallizes on cooling. It dissolves readily in cold 10-per cent. sodic-hydrate solution; on adding an acid, however, the original compound is not precipitated, but a substance that seems to be a mixture of a hydrate and a polymer; for if it is heated it becomes soft at 60°–70°, and if warmed with water becomes sticky and a part (the hydrate) goes into solution while the polymer remains behind. The same change seems to take place to some extent when pyruvic *p*-toluide is dissolved in water, for, on allowing the aqueous mother-liquor from which the toluide was originally crystallized, to stand for some days in the cold, quite a quantity of the polymer separated out. If the sodic-hydrate solution of pyruvic *p*-toluide is made very dilute, the addition of acid produces no precipitate, but, on extracting with ether, a clear ethereal solution is obtained, from which, on standing in the cold, the polymer very slowly separates out in the form of colorless microscopic prisms. This polymer melts at 193°–194°. It is very slightly soluble in water, alcohol, and ether, and somewhat more readily in chloroform. On analysis:

0.1145 gram substance gave 0.0664 gram H_2O and 0.2783 gram CO_2.

0.1311 gram substance gave 0.0818 gram H_2O and 0.3275 gram CO_2.

0.2087 gram substance gave 14.6 cc. N at 22° and 745.6 mm.

	Calculated for $(C_{10}H_{11}NO_2)_m$.	Found.	
C	67.79	66.28	68.12
H	6.21	6.44	6.93
N	7.91	7.85	...

Action of Phenylhydrazine on Pyruvic Paratoluide.—On mixing in the cold an ethereal or alcoholic solution of pyruvic *p*-toluide with the calculated (1 mol.) amount of phenylhydrazine, a substance quickly begins to separate out in the form of microscopic needles. This precipitate is very bulky, soon filling the entire solution when in the proportion of 1 gram pyruvic *p*-toluide to 50 cc. solvent. The reaction never seems to be complete and the

calculated quantity is never obtained. This reaction-product is pyruvic-*p*-toluide phenylhydrazone hydrate, but it loses water so readily that it could not be analyzed. It was prepared for analysis by drying on a clay plate, being pressed between filter-papers, and standing *in vacuo* over sulphuric acid for one hour.

Analyses of three different preparations gave varying figures, all between the hydrazone and the hydrazone hydrate. On heating the freshly precipitated hydrazone hydrate in a capillary tube it partially melts at about 100°, then becomes solid again and finally melts at about 200°. On heating 0.409 gram in an open dish for five hours at 115° in an air-bath it lost 0.0202 gram and did not change in weight by the further heating. If it had been pure hydrazone hydrate it should have lost 0.0259 gram.

Pyruvic-paratoluide phenylhydrazone, $\begin{matrix} CH_3.C_6H_7.N=C\text{-}OH \\ | \\ C_6H_5.NH\text{-}N=C\text{-}CH_3 \end{matrix}$.

—The product obtained by heating the hydrate was crystallized once from alcohol. It then melted at 204°. On analysis:

0.1671 gram substance gave 23.5 cc. N at 16° and 746.3 mm.

0.1335 gram substance gave 0.0777 gram H_2O and 0.3497 gram CO_2.

	Calculated for $C_{17}H_{17}N_3O$.	Found.
C	71.91	71.44
H	6.37	6.47
N	15.72	16.15

This hydrazone can be obtained more simply by heating the hydrazone hydrate in ethereal or alcoholic solution.

The proof that the above bodies are derivatives respectively of mesoxalic, benzoylformic, and pyruvic acids is unnecessary, as it has already been given by Nef[1] in the case of corresponding anilides and orthotoluides.

Action of Formic Acid.—Paratolyl isocyanide reacts with formic acid in the same way as do the other isocyanides that have been carefully studied.[2] 4 grams *p*-tolyl isocyanide were added to the calculated amount (two molecules) of crystallized formic acid at 0°. A lively evolution of gas took place at once. The residue was distilled, giving 3 grams of an oily substance which on crystallization from ether and ligroïn gave colorless crystals

[1] Ann. Chem. (Liebig) **270**, 293, 302, 320.

[2] Gautier: Ann. chim. phys. [4] **17**, 223, 241; Nef: Ann. Chem. (Liebig) **270**, 278, 310.

melting at 54° and identical with formo-*p*-toluide as described by Tobias.[1]

Molecular Rearrangement.—The molecular rearrangement of the isocyanides by heat was first noticed by Weith[2] in the case of phenyl isocyanide. Hofmann[3] obtained the rearrangement of the isocyanides derived from pentamethylamidobenzene and tetramethylamidobenzene. Nef[4] has obtained *o*-tolyl cyanide from *o*-tolyl isocyanide. 5 grams *p*-tolyl isocyanide were heated in a sealed tube for three hours at 210°–225°. On opening the tube the isonitrile smell had entirely disappeared, but much polymerization had taken place. The product was taken up with dry ether to get rid of the polymerized isocyanide. After distilling off the ether the residue was distilled, yielding 3 grams of *p*-tolyl cyanide boiling at 213°–214° and melting at 27°. Paterno and Spica[5] give as the boiling-point 217°–218°, and as the melting-point, 28.5°. Its identity was further proved by saponification with sulphuric acid, giving *p*-tolylic acid[6] melting at 180°.

Paratolyl Isocyanide and Silver Cyanide.—If *p*-tolyl isocyanide and silver cyanide are mixed in the cold, a noticeable evolution of heat ensues, and the mass on being thoroughly mixed becomes solid. 2 grams *p*-tolyl isocyanide and an equal quantity of silver cyanide were mixed in a mortar and rubbed till a dry powder ensued. This was boiled out with 2 liters of water, and on cooling 0.6 gram colorless needles crystallized out. These were filtered off, dried on a clay plate, pressed between filter-papers and analyzed:

0.1537 gram substance gave 0.0511 gram H_2O and 0.2751 gram CO_2.

0.1544 gram substance gave 15.5 cc. N at 21° and 750.8 mm.

0.2165 gram substance gave 0.1055 gram AgCl (Carius).

0.1092 gram substance gave 0.0380 gram H_2O and 0.1916 gram CO_2.

0.1288 gram substance gave 0.0629 gram AgCl (Carius).

Calculated for $\left\{\begin{matrix}AgNC\\C_7H_7NC,\end{matrix}\right.$	for $\left\{\begin{matrix}2AgNC\\3C_7H_7NC.\end{matrix}\right.$	Found.	
C	43.03	50.48	48.81	48.96
H	2.79	3.39	3.69	3.87
Ag	43.03	34.84	36.67	36.76
N	11.16	11.29	11.34	...

[1] Ber. d. chem. Ges. **15**, 2446.
[2] *Ibid.* **6**, 213.
[3] *Ibid.* **17**, 1914; **18**, 1824.
[4] Ann. Chem. (Liebig) **270**, 311.
[5] Ber. d. chem. Ges. **8**, 441.
[6] Fischli: Ber. d. chem. Ges. **12**, 615.

It melts at 118° with decomposition. On boiling out the residue with as much more water more material is obtained, but this does not seem to be as pure and is not so well crystallized. If the clear solution first obtained be boiled for a few moments it becomes turbid from the silver cyanide which separates out. If the crystalline product be washed with alcohol or ether it is decomposed and the residue is much poorer in carbon and hydrogen, as was proved by analysis. The substance is decomposed by heating with potassium-cyanide solution, drops of isonitrile separating out. It is also decomposed by hydrochloric acid, giving silver cyanide. The product and its solutions always smell of isonitrile.

The above experiments agree very well with the supposition that a simple double salt is first formed and that this is then decomposed by the water from which it was crystallized. This is in accordance with the results of Meyer,[1] who obtained a double salt $AgNC.C_2H_5NC$, which was decomposed by alcohol, ether, potassium cyanide, dilute acids, and even by standing in the air. Hofmann[2] states that phenyl isocyanide easily unites with other cyanides, the compound with silver cyanide crystallizing especially well. In the case of *p*-tolyl isocyanide I have been unable to obtain evidence of reaction with any of the metallic cyanides at my disposal, except with silver cyanide.

As was shown by the experiments of Nef[3] the isocyanides easily add two atoms of chlorine, forming alkylated imidophosgenes. These products can be more easily obtained, however, by the action of chlorine on the mustard-oils. From the constitutional resemblance of these compounds to phosgene I was led to investigate the action of sodium alcoholates upon one of them, and found that the analogy of the reactions was very striking. When phenylimidophosgene is treated with sodium alcoholates under the proper precautions, it gives phenylimidochlorformic esters, only one atom of chlorine reacting:

$$C_6H_5.N:C\begin{matrix}Cl\\Cl\end{matrix} + NaOR = C_6H_5.N:C\begin{matrix}Cl\\OR\end{matrix} + NaCl.$$

Under more energetic treatment, however, both chlorine atoms react, giving phenylimidocarbonic esters.

$$C_6H_5.N:C\begin{matrix}Cl\\Cl\end{matrix} + 2NaOR = C_6H_5.N:C\begin{matrix}OR\\OR\end{matrix} + 2NaCl.$$

[1] J. prakt. Chem. **68**, 285. [2] Ann. Chem. (Liebig) **144**, 118.
[3] *Ibid.* **270**, 282, 313, 321.

Phenylimidocarbonyl chloride was prepared from phenyl mustard-oil, according to Nef's modification[1] of the method of Sell and Zierold.[2] A 90-per cent. yield was obtained.

Phenylimidochlorformic ethyl ester, $C_6H_5N=C<^{Cl}_{OC_2H_5}$.—This substance was first prepared by digesting an excess of dry sodium ethylate with an absolute-ethereal solution of phenylimidocarbonyl chloride. This method goes very well, but it is much simpler to use an alcoholic solution of sodium ethylate, as was suggested by Stieglitz and Lengfeld.[3] 17.4 grams phenylimidophosgene were dissolved in a cold mixture of equal parts (15 cc. each) absolute alcohol and dry ether. To this was slowly added a solution obtained by dissolving 2.3 grams sodium in an appropriate quantity of absolute alcohol. An evolution of heat and separation of sodium chloride were at once noticeable. The mixture was kept in a dish of ice-water during the reaction and for about five minutes thereafter. It was then poured into an excess of water, extracted with ether, and the ethereal solution washed six times with water. By extracting the first washings again with ether a considerable increase in the yield can be obtained. The solution was dried with calcium chloride and the ether distilled off (either *in vacuo* or at ordinary pressure). An almost colorless oil was obtained which boiled at 105° at 12 mm. pressure, yielding 16 grams of a colorless, sweet-smelling oil which gave the following figures on analysis:

0.1041 gram substance gave 0.0556 gram H_2O and 0.2247 gram CO_2.

0.2467 gram substance gave 17 cc. N. at 22° and 749.3 mm.

0.3200 gram substance gave 0.2511 gram AgCl (Carius).

	Calculated for $C_9H_{10}NOCl$.	Found.
C	58.84	58.87
H	5.45	5.93
N	7.63	7.73
Cl	19.34	19.42

The combustion must be carried out with great care, as ethyl chloride is easily split off. The same holds true of the Carius determination. It was found necessary to heat for eight hours at 180°, finally raising the temperature to 225° for an hour.

[1] Am. Chem. (Liebig) **270**, 284. [2] Ber. d. chem. Ges. **7**, 1228.
[3] Am. Chem. Jl. **16**, 73.

Phenylimidochlorformic ethyl ester has a specific gravity of 1.144 at 12° (Westphal). It boils at ordinary pressure with slight decomposition, the distillate smelling of phenyl isocyanate. It is quite stable towards water and alkalies, but is easily decomposed by acids. With concentrated hydrochloric acid a violent reaction soon ensues, the ester being split into phenyl isocyanate, which, under the influence of the acid, gives carbanilide, and ethyl chloride, which is given off with ebullition. The same decomposition takes place slowly if the ester is allowed to stand in damp air, but it can be kept indefinitely in a desiccator over potassium hydrate.

The action of aniline on this substance was carefully studied. The reaction is

$$C_6H_5N:C\begin{matrix}Cl\\O-C_2H_5\end{matrix} + 2C_6H_5NH_2 = (C_6H_5NH)_2CO + C_6H_5NHC_2H_5.HCl,$$

as the following experiment proves: 0.7 gram of aniline and an equal amount of the chlorformic ester were carefully mixed in the cold. The mixture was cooled by means of ice till it became solid. It was then gently warmed and treated with cold water acidified with hydrochloric acid. A part went into solution and there was left behind 0.6 gram carbanilide, melting at 235°.[1] The filtered acid solution was made alkaline, giving an oil having the odor of an alkylated aniline. This was taken up with ether, dissolved in an excess of dilute hydrochloric acid, and treated with sodium nitrite. A brown oil separated out, which was volatile with steam, had the characteristic odor of the nitrosamines, and gave Liebermann's reaction with phenol and concentrated sulphuric acid.

Werner[2] has obtained the above-mentioned ester in an impure state by the action of phosphorus pentachloride on ethylsynbenzhydroxamic acid.

Phenylimidocarbonic diethyl ester, $C_6H_5.N=C\begin{matrix}O.C_2H_5\\O.C_2H_5\end{matrix}$.—

After one of the chlorine atoms in phenylimidophosgene has been replaced by the ethoxy group, the second is replaced with much more difficulty. On treating phenylimidocarbonyl chloride in the cold with an alcoholic solution of two molecules of sodium ethylate, the replacement is not complete, but a mixture of chlorformic and carbonic esters results. The best method of procedure was found to be slowly to pour a solution of phenylimidophosgene

[1] Weith: Ber. d. chem. Ges. **9**, 820. [2] Ber. d. chem. Ges. **25**, 38; **26**, 1565.

in dry alcohol and ether into an alcoholic solution of two molecules sodium ethylate, allowing the temperature to rise to about 50°. After standing for half an hour at this temperature the mixture is poured into water and extracted with ether. The ether, after drying with calcium chloride, was distilled off, leaving a colorless oil which, on the second distillation at reduced pressure, boiled at 122° at 12 mm. On analysis:

0.2018 gram substance gave 13.5 cc. N at 20° and 748.5 mm.

0.1358 gram substance gave 0.3416 gram CO_2 and 0.1009 gram H_2O.

0.1547 gram substance gave 0.3889 gram CO_2 and 0.1089 gram H_2O.

	Calculated for $C_{11}H_{15}NO_2$.	Found.	
C	68.39	68.61	68.54
H	7.77	8.25	7.85
N	7.26	7.57	...

The combustion must be conducted with great care, as the compound seems to decompose into gaseous products which are liable to go over unburned. On heating 5 grams of this substance in a sealed tube for five hours at 300° it was completely decomposed and there could be isolated as decomposition-products, aniline, carbanilide and a gas consisting largely of carbon dioxide and unsaturated hydrocarbons.

Phenylimidocarbonic diethyl ester is a colorless and nearly odorless oil. It boils at ordinary pressure at about 245° with some decomposition, as the distillate always smells of phenyl isocyanate. It is stable towards alkalies and water, but is split by dilute hydrochloric acid in the cold—more quickly on warming—into aniline and carbonic diethyl ester. This resembles the decomposition of imidocarbonic diethyl ester, $NH=C<^{OR}_{OR}$, obtained by Sandmeyer,[1] which is split by acids into ammonia and carbonic ester. Sandmeyer also obtained by the action of aniline hydrochloride on the imidocarbonic ester an oil which he was not able to purify, but which he considered to be the phenylimidocarbonic diethyl ester described above.

Phenylimidochlorformic methyl ester, $C_6H_5.N=C<^{Cl}_{OCH_3}$.—This was made from phenylimidophosgene and a solution of

[1] Ber. d. chem. Ges. **19**, 864.

sodium methylate in methyl alcohol in exactly the same manner as the ethyl ester was made from sodium ethylate. It is a colorless, pleasant-smelling oil, exactly analogous to the ethyl ester. It boils at 104° at 15 mm. pressure, and with very slight decomposition at 215° at ordinary pressure. On analysis,

0.1734 gram substance gave 0.3597 gram CO_2 and 0.0782 gram H_2O.

0.2498 gram substance gave 17.8 cc. N at 20.5° and 754.5 mm.

0.1765 gram substance gave 0.1510 gram AgCl (Carius).

Calculated for C_8H_8NOCl.		Found.
C	56.64	56.56
H	4.72	5.02
N	8.26	8.11
Cl	20.94	21.17

Phenylimidocarbonic dimethyl ester, $C_6H_5.N=C<^{OCH_3}_{OCH_3}$.—This compound was made by pouring a solution of phenylimidophosgene in dry ether and alcohol into a methyl-alcohol solution of two molecules sodium methylate, at a temperature of about 50°. The mixture was poured into water, the oil taken up with ether, and, after drying and distilling off the ether, distilled at reduced pressure. It boils at 123.5° at 16 mm. pressure. On analysis:

0.1610 gram substance gave 0.3847 gram CO_2 and 0.0982 gram H_2O.

0.2338 gram substance gave 17.2 cc. N at 18° and 748.8 mm.

	Calculated for $C_9H_{11}NO_2$.	Found.
C	65.44	65.15
H	6.67	6.78
N	8.48	8.40

It is a colorless oil, of very slight odor, entirely analogous to the diethyl ester. Treated with aniline in the cold it gives carbanilide. Treated with aniline hydrochloride in methyl-alcohol solution it gives the same product.

Phenylimidochlorformic phenyl ester, $C_6H_5.N=C<^{Cl}_{OC_6H_5}$.—8.7 grams phenylimidophosgene were dissolved in 20 cc. absolute ether and an equal quantity of absolute alcohol was added. The mixture was cooled with ice-water, and to it was slowly added a

solution made by dissolving 1.15 grams sodium in absolute alcohol and adding to it 4.7 grams phenol. An immediate precipitation of sodium chloride was noticeable. The mixture was kept cold with ice for a few minutes and then allowed to stand in a dish of cold water for two hours. It was then poured into an excess of cold water and the oil taken up with ether. The ethereal solution was washed with sodic hydrate to remove any excess of phenol and then repeatedly washed with water. After drying with calcium chloride, the ether was distilled off and the residue distilled at reduced pressure. The oil commenced to boil at about 100° (12 mm.). The thermometer quickly rose to 164°, and the main fraction (7 grams) distilled between 164° and 168°. This was redistilled, boiling at 168° at 12 mm. pressure. On analysis:

0.2096 gram substance gave 0.0880 gram H_2O and 0.5194 gram CO_2.

0.3932 gram substance gave 21.4 cc. N at 23.5° and 748.3 mm.

0.2040 gram substance gave 0.1257 AgCl (Carius).

	Calculated for $C_{13}H_{19}NClO$.	Found.
C	67.39	67.57
H	4.32	4.66
N	6.05	6.06
Cl	15.33	15.25

This ester is a colorless oil which has an odor resembling the ethyl ester, but much fainter. On cooling it solidifies to a white crystalline solid which melts at 43°. It is quite stable toward alkalies, but with hydrochloric acid gives carbanilic phenyl ester,[1] melting at 124°. On treating with two molecules aniline and heating till a decided reaction took place, the hydrochloride of α-triphenylguanidine[2] was the only product that could be isolated from the resultant mixture. On treating with one molecule aniline and keeping the mixture cool, various mixtures of carbanilide and α-triphenylguanidine hydrochloride were obtained.

[1] Hofmann: Ber. d. chem. Ges. **4**, 249.

[2] Merz and Weith: Zeit. f. Chem. **1868**, 513; Hofmann: Ber. d. chem. Ges. **2**, 453.